project record

Firefighters Physiological Study

ED&T 2003
FIREFIGHTING EFFICIENCY OF MAN -- THE MACHINE

JUNE 1974

U.S. Department of Agriculture
Forest Service,
Equipment Development Center
Missoula, Montana

PROJECT RECORD

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FIREFIGHTING EFFICIENCY OF MAN--THE MACHINE

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ABSTRACT

A study was designed to provide information needed to relate normal work demands to those where heat is a factor, develop guidelines for worker rest requirements, update fireline production guides, relate the physical demands of various fire tasks to physical fitness and experience, establish production rates for various tools and gather information for use in designing tools, clothing and equipment.

Physiological and environmental data were gathered on selected firefighters working on 39 brush and timber fires. Included were such items as wet globe temperature, fireline production, worker pulse, fireline grade, rate of spread and resistance to control, smoke, elevation and size of crew.

It was found that firefighters are occasionally exposed to hot, stressful conditions that could cause heat related illnesses. Worker rest breaks are not always adequate and water consumption is at times below the amount needed to offset sweat loss. Physical demands and production rates for various tools and tasks could not be established. Unmeasured variables including skill, training, motivation and supervision apparently have a significant effect on fireline production rates.

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INTRODUCTION

The effect of high temperature environments on man's ability to perform work is beginning to gain national recognition. This is evidenced by work by the National Institute for Occupational Safety and Health (NIOSH) to develop standards for Occupational Exposure to Hot Environments.

The Forest Service has long recognized that hot environments can be a potential health and safety hazard to men combating forest, range and brush fires. This project, ED&T 2003 - Firefighting Efficiency of Man--The Machine, was initiated in 1969 to learn more about man's work performance and physiological needs while fighting fires. This is the second in a series of reports covering these studies.

To review briefly, the objectives of this project were:

1. Relate normal work demands to those where extreme heat is a factor.

2. Provide guidelines for worker rest requirements.

3. Update information on fireline production rates.

4. Establish physical demands for various fire tasks with relation to physical fitness and experience.

5. Establish production rates for various tools such as pulaskis, McLeods, and flail trenchers.

6. Gather data for use in designing tools, clothing, and safety equipment.

The original plan for this study was prepared in cooperation with Dr. Brian Sharkey of the University of Montana. In 1969, fitness levels and other background information were collected on two 25-man Interregional (IR) fire crews and a data collector assigned to travel with them to fires. Data were collected on 11 fires, but little beneficial information was gained as less than 100 chains of line were constructed and the crews were never under any real stress from the fire or work environment.

In an effort to gather the desired initial attack data the study was changed to the Missoula Smokejumper Unit for the 1970 season. For various reasons the single data collector was unavailable for the few hot fires that occurred, and again little meaningful information was gathered that could be applied toward the project objectives. Project activities during the 1969 and 1970 seasons are covered in greater depth in a project record, ED&T 2003, entitled *Firefighting Efficiency of Man--The Machine*, dated June 1971. This report covers project progress since the June 1971 report.

DATA COLLECTION - 1971 and 1972 SEASONS

After two relatively unsuccessful seasons the project was expanded to six Interregional crews located in several Western Regions. In 1971 the following crews were selected on a basis of location, length of season, and the likelihood of collecting substantial data.

Northern Region (R-1)

Bitterroot National Forest IR Crew
Nezperce National Forest IR Crew

California Region (R-5)

Northern California Service Center IR Crew
Cleveland National Forest IR Crew

Pacific Northwest Region (R-6)

Wallowa-Whitman National Forest IR Crew
Rogue River National Forest IR Crew

The following crews participated in 1972:

Northern Region (R-1)

Bitterroot National Forest IR Crew
Nezperce National Forest IR Crew

Rocky Mountain Region (R-2)

Pike National Forest IR Crew

Intermountain Region (R-4)

Sawtooth National Forest IR Crew

California Region (R-5)

Oak Grove Crew (Angeles National Forest)
El Cariso IR Crew (Cleveland National Forest)

The data collectors were selected from crewmembers having forestry, physical education, or related educational backgrounds. In 1971, four of the data collectors were brought to Missoula for a 1-day training session. The remaining data collectors were trained at their home bases. In 1972, all data collectors were trained at their home bases.

DATA COLLECTION EQUIPMENT

The form for data collection was revised and reduced to letter size (appendix 1). The Bureau of Land Management (BLM) fuel-type guides were adopted as they are more uniform throughout the West and therefore easier to work with. Each data collector was supplied with the following equipment:

Wet globe thermometer (WGT) instrument[1/]
Distilled water bottle
Disposable canteen
Equipment pack, belt, and suspenders
Stopwatch
100-foot tape
Plastic ribbon
Pocket sling psychrometer
Clinometer
Data sheet holder and instructions
Instrument leg

They were also supplied with a bench, scale, and metronome, which were used to give the Forest Service physical fitness test to crewmembers. All of the equipment is shown in figure 1.

Figure 1.--Physiological study equipment.

1/ A small, lightweight instrument that combines air temperature, humidity and the effects of air movement and thermal radiation into a single reading.

Data Recording Procedures

Detailed instructions for recording data are included in appendix 2. All measurements were generally taken at 30-minute intervals with the pulse count recorded on three or four individuals. The WGT instrument was placed as close to the fireline as possible and in the area where the three or four subjects were working (fig. 2). It was supported at the mean level of the worker's body while in the line building position. Wet and dry bulb temperatures were also taken, mainly for a check on the WGT readings. Slope and fireline grade were measured with the clinometer.

Figure 2.--Reading WGT instrument.

Fireline grade was recorded as plus or minus percent, depending on the direction the crew was working. The rate of spread and resistance to control were determined from the BLM fuel-type guides, and a numerical designation then given to the dual Hornby letter system which is a combined rating using low, medium, high and extreme for rate of spread and resistance to control. The flame height and width, along with depth of the flame front were also recorded. This information was gathered for checking the WGT readings, which includes the effects of radiant heat.

Cleared width of the fireline was measured as the amount of ground and aerial fuels that were cleared away during line construction. The actual fireline length and width were recorded and used in the analysis to calculate both length and square feet of fireline produced. The work task was listed as line construction, mopup, or other. The specific task was recorded for each subject as follows: digging-pulaski, digging-shovel, clearing-pulaski, and clearing-chain saw. A smoke rating system was developed for the study and contained the following five categories:

Smoke

1 - Clear.
2 - Smoke light, little irritation.
3 - Irritation to eyes. Some difficulty in breathing.
4 - Much eye irritation, periodic work stoppage due to difficulty in breathing.
5 - No work possible--men driven out.

The pulse was taken either at the subject's wrist or the carotid artery along the throat (fig. 3). Only a 15-second count was taken in an effort to minimize work interruption. When possible, pulse counts were also taken just prior to the subject's return to work after a rest break. Length of break was also recorded in an attempt to determine if the generally accepted

Figure 3.--Taking firefighter's pulse count.

rest periods are adequate. A perceived effort rate was recorded periodically on each subject. This was his feeling on the difficulty of the task he was doing and was given a ranking of from 1 to 21 from the following scale:

Effort

1
2
3 - Extremely light
4
5 - Very light
6
7 - Light
8
9 - Fairly light
10
11 - Neither light nor difficult
12
13 - Fairly difficult
14
15 - Difficult
16
17 - Very difficult
18
19 - Extremely difficult
20
21

Physiological studies by others have shown that the perceived effort ratings given a particular task by individuals will correlate inversely with their fitness levels. They feel that the body acts as a modified computer which summarizes the environmental and physiological conditions and comes up with a composite rating on the difficulty of the task.

The total number of men on a specific work task was also recorded at the time other data were taken. Information on the subject's previous activities, sleep, and food and water consumption was recorded on the back of the data form.

Plans for Analyzing Data

The original study plan, prepared in cooperation with the University of Montana Human Performance Laboratory, contained the following proposal for analysis of data:

Analysis

Data analysis will require extensive tabulation and organization prior to any graphic or statistical treatment. Objectives of the analysis are to assist in the formation of probability statements regarding specific objectives of the study.

(1) Multiple regression analysis to facilitate prediction of production from WGT, fitness, percent slope, fuel type, smoke, hours, days work, etc.

Generate correlation matrix (computer) relating pertinent variables. Calculate contribution of each to prediction of production. Develop a prediction equation and monograms from significant contributors.

(2) Relate exercise pulse rates to physical fitness of subject engaged in various firefighting tasks.

(3) Relate work demands under severe environmental conditions - factorial analysis of variance design using levels of WBGT2/ and levels of fitness. Exercise pulse rates, pulse recovery times are both to be analyzed.

(4) Analysis of variance design relating levels of WGT and hours or days on job - production rates would serve for analysis.

(5) Graphic presentation of data indicating production rates under various conditions, pulse rates for various conditions, recovery pulse rates, etc.

(6) Attempt to formulate a degree of difficulty scale that incorporates WBGT, percent slope, smoke, fuel type and relate difficulty to perceived exertion ratings (includes also the hours, days on job). Similar prediction methodology as in 1 preceding deemed appropriate.

2/ Wet Bulb Globe Thermometer index which was used in the initial portion of the study.

Data Acquired

During the 1971 fire season the six crews submitted 25 separate sets of data obtained on a total of 23 fires. In 1972, the six crews submitted 23 sets of data collected on 16 fires.

On two occasions three of the crews involved in the study were on the same fire. The location, fire name and duration of data collection are summarized by crews and seasons in tables 1 and 2.

Table 1.-- *Data collection summary, 1971*

CREW	REGION	FOREST	DATE	FIRE NAME	DAYS COLLECTING DATA
BITTERROOT (R-1)	6	OLYMPIA	JULY 31	SKYLINE	2
	1	KANIKSU	AUG 6	S. F. BULL RIVER	2
	1	DEERLODGE	AUG 9	E. RIDGE	1
	1	BITTERROOT	AUG 10	KURTZ CREEK	1
	1	LOLO	AUG 12	WOODMAN SADDLE	1
	1	KANIKSU	AUG 12	TRAPPER CREEK	4
	1	LEWIS & CLARK	AUG 20	O HEARN	2
	1	NEZPERCE	AUG 22	POLLOCK	2
	4	SALMON	AUG 31	DUTCH OVEN	1
	4	HUMBOLDT	SEP 2	MC CONNELL	2
NEZPERCE (R-1)	1	HELENA	AUG 6	AMERICAN BAR	2
	BLM	LEWISTOWN MT.	AUG 10	NEWHOUSE COULEE	3
	1	HELENA	AUG 21	BLUE CLOUD	2
	1	HELENA	AUG 21	RATTLESNAKE GULCH	1
REDDING (R-5)	5	LOS PADRES	AUG 8	SQUAW	1
	5	LOS PADRES	AUG 31	BLUE	1
	5	LOS PADRES	OCT 7	RAMERO	2
CLEVELAND (R-5)	5	CLEVELAND	AUG 6	CASE	1
	5	CLEVELAND	AUG 26	ANAHUAC	2
	5	LOS PADRES	AUG 30	BLUE	1
	5	MENDOCINO	SEP 14	TOP	1
WALLOWA-WHITMAN (R-6)	1	NEZPERCE	AUG 21	POLLOCK	2
ROGUE RIVER (R-6)	6	OLYMPIC	AUG 21	TRAP PASS	1
	6	WENATCHEE	AUG 11	SWANKE PASS	1
	6	WALLOWA-WHITMAN	AUG 29	WILD SHEEP	1

Table 2.--*Data collection summary, 1972*

CREW	REGION	FOREST	DATE	FIRE NAME	DAYS COLLECTING DATA
BITTERROOT (R-1)	NPS	MESA VERDE N. P.	JULY 12	LITTLE MOCCASIN CR.	3
	4	FISH LAKE	JULY 20	SHEEP ROCK	6
	4	SALMON	JULY 29	BUTTS CR.	2
	1	BITTERROOT	AUG 11	ST. CLAIR	1
	4	SALMON	AUG 12	GOAT CR.	4
	1	BITTERROOT	AUG 19	CACHE CR.	1
	5	LOS PADRES	AUG 24	BEAR	4
	1	LOLO	AUG 30	PLANT CR.	5
NEZPERCE (R-1)	5	LOS PADRES	AUG 4	MOLERA	1
	5	LOS PADRES	AUG 24	BEAR	4
PIKE (R-2)	NPS	MESA VERDE N. P.	JUNE 21	ROCK SPRINGS CR.	1
	NPS	MESA VERDE N. P.	JULY 13	LITTLE MOCCASIN	1
SAWTOOTH (R-4)	4	FISH LAKE	JULY 12	BALDWIN RIDGE	4
	4	FISH LAKE	JULY 21	SHEEP ROCK	2
	5	LOS PADRES	AUG 3	MOLERA	2
	4	SALMON	AUG 10	DRY GULCH	1
	4	SALMON	AUG 12	GOAT CR.	2
	5	LOS PADRES	AUG 24	BEAR	2
	5	KALAMATH	SEP 4	BIG	1
CLEVELAND (R-5)	5	LOS PADRES	AUG 12	MOLERA	3
	5	CLEVELAND	OCT 1	SKY	1
	5	PLUMAS	OCT 25	CHAMBERS	2
ANGELES (R-5)	5	TAHOE	AUG 15	OWL CR.	1

DATA ANALYSIS

For computer analysis, the data were transferred from the field sheets to a 80-column data coding form. Measurements taken at each time interval became a data line on the coding form. Production was recorded in three ways, square feet of scraped line, square feet of line per man-hour, and linear feet of line per man-hour. Worker pulse and perceived effort were recorded as an average of the subjects being checked. The crew fitness was the average fitness level for the entire crew taken after training but prior to the main fire season.

Statistical Analyses

The following numbers were assigned to each of the variables used in the analysis:

X(1) = WGT
X(2) = Fireline grade (± %)
X(3) = Resistance to control
X(4) = Smoke
X(5) = Production (sq. ft.)
X(6) = Time (hrs.)
X(7) = Number of men
X(8) = Production (sq. ft./man-hr.)
X(9) = Crew fitness
X(10) = Worker pulse
X(11) = Perceived effort
X(12) = Elevation
X(13) = Hours on job
X(14) = Production (ft./man-hrs.)
X(15) = Slope (%)
X(16) = Rate of spread

The data from each year were fed into the GSA time-share computer in Atlanta. In the analysis, X(14) - Production (ft./man-hrs.) was used as the dependent variable. The data were analyzed in a series of steps with the technique constant and only the selection of variables changing. The variables selected were the ones considered to have the greatest effect on fireline production. The correlations were run first with all of the variables and then progressively dropping one of the variables each run. Table 3 shows results of the run with the first year's data, the second year's data and then with all of the data combined. R is the overall correlation coefficient, R-squared is the percentage of variation in production, X(14), that is explained by the variation in the independent variables considered.

Table 3.--*Comparison of the variables affecting production*

1ST SET OF DATA			2ND SET OF DATA			COMBINED DATA		
VARIABLE	R	R-SQUARED	VARIABLE	R	R-SQUARED	VARIABLE	R	R-SQUARED
X(7)	.382677	.146442	X(3)	.321794	.103551	X(12)	.315329	.099432
X(12)	.630363	.397357	X(12)	.406203	.165001	X(7)	.44782	.200542
X(13)	.664352	.441364	X(7)	.459995	.211595	X(13)	.482693	.232993
X(1)	.683123	.466657	X(13)	.487414	.237573	X(3)	.52145	.27191
X(4)	.70057	.490799	X(15)	.498304	.248307	X(16)	.536654	.287997
X(11)	.696885	.485649	X(10)	.518610	.268956	X(15)	.543348	.295227
X(15)	.704946	.496949	X(16)	.541580	.293309	X(10)	.550341	.302876
X(2)	.707113	.500009	X(1)	.547902	.300197	X(4)	.554217	.307157
X(10)	.707187	.500113	X(9)	.547361	.299604	X(1)	.554464	.30743
X(16)	.70911	.502837	X(11)	.545868	.297971	X(2)	.553917	.306824
X(9)	.70852	.502001	X(2)	.543700	.295609	X(11)	.551881	.304572
X(3)	.703417	.494796	X(4)	.540900	.292573	X(9)	.549741	.302215

A least-squares linear equation was fitted using all the variables, then the variables were dropped according to the probability of getting such a relation by random chance with uncorrelated data. For example, in the first set of data X(7) is correlated with production to an extent that could most easily be caused by random chance. Similarly, also in the first set of data, X(3) is correlated with production to an extent that could be least likely the result of random chance. The drastic change in importance of some variables from one set of data to another, particularly X(3) has not been explained.

In looking at the printout of the combined data, there is little effect on production, X(14), as the first six variables are dropped. The remaining six variables include X(15) slope, X(16) rate of spread, X(3) resistance to control, X(13) hours on job, X(7) number of men, and X(12) elevation. Of these, it is difficult to explain how elevation would have the greatest effect on line production, especially when it is a positive relation, i.e., the higher the elevation the greater the line production per man-hour.

When looking at both years' data separately it is also difficult to explain how X(3), resistance to control, had little effect on production in the first year's data but had the greatest effect the second year. There are several things that could cause this, including judgment errors with the recorders, an inadequate amount of data or other variables that were not measured. Several of these could be as important as the variables that were measured and include items such as crew skills, training, motivation and supervision.

Supplementary Analyses

To meet the project objectives certain other analyses were done.

Fireline production rates.--The measurement of constructed fireline resulted in the most conclusive data collected during the study. Production in feet-per-man-hour is the dependent variable used in the statistical analyses and is interesting when compared with present handline production rate guides. To be able to better examine and compare the measured rate of handline construction the data were converted to chains-per-man-hour.

These data are shown in table 4, along with the fuel type, resistance to control rating, length of period worked, and the number of men in the crew. Also shown for comparison are several production rate guides, including one for the new fuel modeling system.

In certain fuel types, line production was measured over a fairly long period of time on several fires and there is a considerable range in the chains of line per man-hour constructed. Although not recorded it can be assumed that the construction rate includes some time that was spent "holding" the line that was constructed.

Although extensive revision of line production guides is not possible, for certain fuel types the measured rates should be valuable to field people and fire planners.

Table 4.--*Rest period and recovery pulse data*

Shift	Crew	Total time of shifts (hours)	Time weighted average– WGT	Subject 1 Average working pulse	Subject 1 Rest period (minutes)	Subject 1 Recovery pulse	Subject 2 Average working pulse	Subject 2 Rest period (minutes)	Subject 2 Recovery pulse	Subject 3 Average working pulse	Subject 3 Rest period (minutes)	Subject 3 Recovery pulse
FY 72 1	CLEVELAND NF	5.5	76	102		80	148		128	103		76
						92			100			80
						76			96			84
2	CLEVELAND NF	1.0	67.5	71		64	96		84	96		76
3	CLEVELAND NF	3.0	65.4	134		92	114		72	133		100
4	CLEVELAND NF	3.5	71.5	126		60	97		76	142		96
5	ROGUE RIVER	3.0	66.2	149			156			138		
5	ROGUE RIVER	7.0		122	15	76	138	15	80	131	15	88
					15			15	92			
6	ROGUE RIVER	3.0	76	125		100	139		96	122		89
7	NCSC	INSUFFICIENT DATA										
8	NCSC	3.5	72.6	83		68	93		80	97		92
9	NCSC	2.0	66.3	104		86	84		84	88		68
10	NCSC	2.5	81	129	5	104	117	5	84	103	5	103
11	SLATE CREEK	2.5	63.7	92		74	115		92	93		72
12	BITTERROOT	1.0	69	144			124			130		
13	BITTERROOT	INSUFFICIENT DATA										
14	BITTERROOT	3.5	64.8	111	5	88	114	5	84			
15	BITTERROOT	1.0	64	144		80	142		84	138		116
FY 73 16	BITTERROOT	10.3	54.5	124	5	96	105	6	64	115	7	76
					9	88		10	64		12	56
					6	116						
17	BITTERROOT	9.0	60.2	106	6	68	119	5	68	114	7	68
					6	68		10	76		5	72
18	BITTERROOT	4.5	64.6	131	10	84	124	1	92	138	15	96
								10	96			
19	BITTERROOT	7.0	68.6	145	10	132	129	10	88	141	14	112
					5	108		9	92		5	84
											7	80
20	BITTERROOT	6.5	60	113			125			116		
21	BITTERROOT	9.6	58.6	114	5	84	114	5	72	116	5	76
22	BITTERROOT	5.0	56.9	101	10	84	93			113	10	80
23	BITTERROOT	3.6	50.4	114			131					
24	BITTERROOT	INSUFFICIENT DATA										
25	BITTERROOT	2.8	47.8	143	10	112	143	10	88	144	10	80
26	BITTERROOT	7.0	76	134	5	88	138			132	5	
27	BITTERROOT	7.5	66.9	125	10	96	105	10	76	94	10	94
28	SLATE CREEK	5.0	68.6	96	15	76	121	15	108	97	15	64
					30	76		30	96		30	56
29	SLATE CREEK	6.5	62.5	90	30	80	82	30	68			
30	SLATE CREEK	10.5	57.6	92			111	15	70	81	15	60
31	SLATE CREEK	1.0	69.5	94			78			104		
32	PIKE	4.5	67.9	131	15	124	119	15	112	137	15	120
									104			
33	PIKE	4.8	58.9	122	10	104	123	10	84	128	10	100
34	SAWTOOTH	2.8	69.3	107			94	5	76	106		
35	SAWTOOTH	5.4	70.2	121	5	108	125	5	100	119	5	104
								5	108		5	116
36	SAWTOOTH	4.3	74	88			94			102		
37	SAWTOOTH	5.5	66.6	109	15	88	99	15	88	101	15	80
					10	100		10	88		10	84
					15	76		15	72		15	84
38	SAWTOOTH	7.5	60.2	108	5	76	112	5	88	112	5	80
					15	88		15	96		15	80
					15	84		15	88		15	88
39	SAWTOOTH	7.8	57.3	118	15	72	103	15	84	98	15	80
					5	100		5	84		5	72
					5	100		30	80		5	84
					15	72					5	84
					15	72					30	60
40	SAWTOOTH	6.5	63.9	98		68	94		72	102		80
						76			80			76
41	SAWTOOTH	12.9	73.9	114	5	88	111	5	92	121	5	100
					15	100		15	92		15	104
					15	104		15	104		15	104
					15	88		15	84		15	88
42	SAWTOOTH	2.5	65.3	92			82			88		
43	EL CARISO	4.7	52.7	115		96	107		84			
						92						
44	EL CARISO	6.3	69.1	135		104	144		116	125		
						104			104			
						100			96			
45	EL CARISO	4.0	57.8	89		76	85		68	97		
						72			88			

Proposed standards for Occupational Exposure to Hot Environments.--When the Occupational Safety and Health Act of 1970 was passed, it emphasized the need for standards to protect workers from potential hazards. The National Institute for Occupational Safety and Health (NIOSH) was given the responsibility for development of the criteria and recommended standard for hot environments. A criteria document, based on the best information available, was published by NIOSH in 1972. The purpose of the proposed standard is to protect against heat-induced illness, be amendable to techniques that are valid, reproducible and available to industry and official agencies and be attainable with existing technology. Research is continuing both in NIOSH and industry to provide necessary data for a more detailed standard. The initial proposed standard is shown in appendix 3. Fire revisions have since been made and the final standard will be published soon.

Although this project began before the proposed standard was drafted, all of the field data collected are usable for comparison with the standard. The WGT index was used in this study in lieu of the WBGT index because the WGT instrument is easier to work with in the field. These readings can be easily converted to the equivalent WBGT values. The equivalent WGT values have been added where WBGT is shown in the proposed standard in appendix 3.

To determine if the time-weighted average WGT values in section 3, (c) of the standard were exceeded in the field data, the time-weighted WGT readings were calculated and are shown in table 5. For the shifts where adequate data were available the 72° WGT value was exceeded on seven occasions.

Of the work practices recommended when the high WGT threshold is reached, acclimatization and physical fitness of workers are important considerations. Heat disorders are, for example, most likely to occur in crews that are moved from northern areas to early or late season fires in Southern California or the Southwest and in crews comprised of unfit or older individuals. Dispatchers should consider these factors when ordering and dispatching crews.

The standard also recommends providing a minimum of 8 quarts of cool 0.1 percent salted water or 8 quarts of water with salt tablets per man per shift. On four occasions in 1973 the test subjects consumed 6 quarts of water during the shift but the average for all fires was near 2 quarts per shift. Although in some cases water may have been taken from streams and not recorded, the water intake for the crews participating in the study was much below the minimum recommended in the standard. It is essential that water intake be about equal to the amount of sweat produced each day and work in a hot environment may result in sweat productions of from 1 to 3 gallons per day. Studies have shown that even if an ample supply of cool water is available, thirst alone is not an adequate drive to stimulate a person to drink enough water to replace sweat losses.

The salt lost from the body must also be replaced and this appears to be particularly high in individuals not acclimatized to the hot environment. After the individual becomes acclimatized the salt content in the sweat is much less. The salt can be replaced by liberal salting of food or drinking 0.1 percent salt solution drinking water. About one level tablespoon of table salt in 15 quarts of water will make a 0.1 percent salt solution.

Table 5.--*Fireline production rates*

	STUDY DATA						PRODUCTION RATE GUIDES			
	FUEL TYPE INDEX *	RESISTANCE TO CONTROL	TIME CONSTRUCTING LINE (HOURS)	CREW SIZE	CONSTRUCTION RATE (CHAINS PER MAN-HOUR)		COMPARABLE FS FUEL TYPE OR FUEL FUEL RESISTANCE RATING	RATE PER MAN-HOUR FROM GUIDES (CHAINS PER MAN-HOUR)	FUEL MODEL	FUEL MODEL PRODUCTION RATE GUIDE (CHAINS PER MAN-HOUR)
NORTHERN ROCKY MOUNTAIN FUEL TYPE	82.3—23	L	.5	21	.15				C	3.0 — 4.0
			3.6	16	.87		**		C	3.0 — 4.0
			2.8	13	.35		L	2.5	C	3.0 — 4.0
			13.0	20	.32				C	3.0 — 4.0
	82.3—25	M	14.3	18	.65		M	1.5	C	3.0 — 4.0
	82.3—30	M	3.0	14	1.34		M	1.5	G	.3 — .7
			7.5	15	.63				G	.3 — .7
	82.3—35	H	4.5	19	.39		H	.6	B	.5 — .9
			5.0	21	.33				B	.5 — .9
	82.3—46	L	2.5	21	.71		L	2.5	A	4.0 — 5.0
COLO.—WYO. FUEL TYPE	82.4—42	L	7.5	20	.72		L	2.5	A	4.0 — 5.0
			9.3	21	.63					
CALIFORNIA FUEL TYPE	82.5—17	M	6.0	20	.75		R—5 NO. 5 ***	2.7	F	1.2 — 2.0
	82.5—18	M	4.7	10	.66		R—5 NO. 6	1.4	F	1.2 — 2.0
	82.5—19	M	7.0	25	.28		R—5 NO. 6	1.4	F	1.2 — 2.0
			5.0	13	.47		R—5 NO. 6	1.4	F	1.2 — 2.0
	82.5—26	H	5.0	21	.15		R—5 NO. 11	.7	D	1.0 — 1.8
			1.0	20	.14		R—5 NO. 11	.7	D	1.0 — 1.8
			4.5	19	.19		R—5 NO. 11	.7	D	1.0 — 1.8
			2.0	10	.78		R—5 NO. 11	.7	D	1.0 — 1.8
			1.0	11	.38		R—5 NO. 11	.7	D	1.0 — 1.8
	82.5—27	H	11.5	21	.32		R—5 NO. 12	.7	B	.5 — .9
			10.5	18	.12		R—5 NO. 12	.7	B	.5 — .9
			4.5	21	.12		R—5 NO. 12	.7	B	.5 — .9
			2.0	21	.21		R—5 NO. 12	.7	B	.5 — .9
	82.5—28	H	2.5	11	.34		R—5 NO. 13	.4	B	.5 — .9
			3.5	21	.35		R—5 NO. 13	.4	B	.5 — .9
			1.5	8	.47		R—5 NO. 13	.4	B	.5 — .9
	82.5—29	M	3.0	13	.56		R—5 NO. 15	.5	E	3.5 — 4.5
PACIFIC NORTHWEST FUEL TYPE	82.6—2	M	10.3	14	.46		M (D 3) ****	3.15	F	1.2 — 2.0
	82.6—3	E	3.0	24	.25		E (D2, C, H)	.46	G	.3 — .7
	82.6—5	H	3.0	24	.23		H (D2, C, RA)	1.22	G	.3 — .7
	82.6—10	M	4.0	24	.32		M (PPI)	3.15	E	3.5 — 4.5

* TYPE NUMBERS ASSIGNED TO BLM FUEL TYPES BY MISSOULA EQUIPMENT DEVELOPMENT CENTER

** FROM R-1 AND R-2 FIRELINE NOTEBOOK RATES GIVEN FOR TRAINED FOREST CREWS

*** FROM 1969 R-5 FIRELINE NOTEBOOK

**** FROM R-6 FUEL TYPE GUIDE AND R-6 FIRELINE NOTEBOOK. RATES FROM 13 FUEL TYPES GROUPED INTO 4 RESISTANCE TO CONTROL CLASSES

The importance of appropriate protective clothing and equipment must also be recognized when exposed to hot environments. Studies[3] have shown that ordinary work clothing can reduce radiant heat transfer by from 30 to 40 percent. It has also been shown that this clothing can reduce the potential for evaporating perspiration by about 40 percent. As the relative humidity is generally quite low on wildfires, adequate evaporation is seldom a problem. Therefore, a firefighter's clothing should be designed to protect against radiant heat as much as possible but be loose fitting and porous enough to enhance evaporation. Both of these conditions become significant when air temperature and/or radiant temperature exceeds body temperature. These same laboratory studies have shown that radiant heat which is tolerable to a worker wearing shirt and pants would be excessive for a man dressed only in shorts.

The standard also encourages mechanization of tasks performed in hot environments to minimize or reduce the physical workload and accomplishing the work during cool periods. In terms of fighting wildland fires this suggests that more mechanization is needed in fireline construction and more work should be done in the cool periods of the day and at night. A good option available to firefighters where heat stress is a problem is to move the fireline away from the radiant heat source.

Worker rest requirements.--The criteria document for occupational exposure to hot environments (appendix 3) states that Brouha[4] and Fuller[5] recommend limits based on the concept of accumulation of cardiovascular strain. They conclude that the worker's pulse rate should not be above 110 beats per minute after a 1-minute rest period and drop to 100 beats per minute within 3 minutes' recovery time. The document further states that the validity of this principle seemed to be upheld in recent industry studies.

To determine if the rest breaks normally given firefighters are adequate, the subjects' recovery pulses were recorded whenever practical. The length of break was also recorded in most cases. This data, along with length of shift, time-weighted average WGT, and average working pulse rate are listed in table 6.

Of the rest periods recorded, all were at least 5 minutes in length and ranged up to 30 minutes. Recovery pulse was recorded 169 times, and of these, 39 or 23 percent, were 100 beats per minute or higher. If the recovery pulse had been taken after 3 minutes' rest, as recommended by Brouha and Fuller, there would have been several additional counts above 100 beats per minute.

In the 17 work shifts where recovery pulse counts of over 100 occurred, the weighted WGT was above 72 on five, or 29 percent, of the shifts. For all of the shift periods (42) where data were collected, the weighted WGT was above 72 on seven, or only 17 percent. The 72 WGT reading is the threshold level for hot environmental conditions shown in the criteria document (appendix 3). As these data were generally collected only during actual fireline construction, the length of shift does not indicate the total length of time the crew was exposed to the hot environment. For the 17 shifts where high recovery pulses were recorded, the average shift length was 5.55 hours. For all of the shifts the average shift length was 5.05 hours. From this it appears that the length of shift had little to do with the high recovery pulses, or in other words,

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3/ Belding, H. S., B. A. Hertig and M. L. Reidesel. Laboratory simulation of a hot industrial job to find effective heat stress and resulting physiologic strain.

4/ Brouha, L. Physiology in industry.

5/ Fuller, F. H. and L. Brouha. New engineering methods for evaluating the job environment.

fatigue accumulation. Fitness is an important factor but it is also evident that the crews are doing a good job in pacing themselves. It does appear, however, that the time-weighted WGT values above 72 have a great deal to do with the high recovery pulse rates. These data are insufficient for prescribing optimum rest breaks for fire crews, but they do indicate that when the WGT value is above 72, the rest breaks should be adjusted to allow the worker's recovery pulse rate to drop to 100 beats per minute or below.

Table 6.--*Time-weighted average WGT values per shift*

SHIFT (FY 72)	AVERAGE WGT	SHIFT (FY 73)	AVERAGE WGT	SHIFT (FY 73)	AVERAGE WGT
1	76	16	54.5	31	69.5
2	67.5	17	60.2	32	67.9
3	65.4	18	64.6	33	58.9
4	71.5	19	68.6	34	69.3
5	66.2	20	60	35	70.2
6	76	21	58.6	36	74
7	INSUFFICIENT DATA	22	56.9	37	66.6
8	72.6	23	60.4	38	60.2
9	66.3	24	INSUFFICIENT DATA	39	57.3
10	81	25	47.8	40	63.9
11	63.7	26	76	41	73.9
12	69	27	66.9	42	65.3
13	INSUFFICIENT DATA	28	68.6	43	52.7
14	64.8	29	62.5	44	69.1
15	64	30	57.6	45	57.8

AVERAGE WGT BASED ON THE FOLLOWING FORMULA—

$$\frac{\left(\frac{WGT_1 + WGT_2}{2} \times t_2\right) + \left(\frac{WGT_2 + WGT_3}{2} \times t_3\right) + \ldots \left(\frac{WGT_{N-1} + WGT_N}{2} \times t_N\right)}{t_2 + t_3 + \ldots\ t_N}$$

NIOSH SYMPOSIUM

As a part of the continuing work of developing a usable standard for hot work environments, a NIOSH Symposium was held in Pittsburgh, February 27-28, 1973. At the request of the Washington Office Division of Fire Management, Division of Engineering, and the National Safety Officer, Art Jukkala from MEDC and Dr. Brian Sharkey from the University of Montana Human Performance Laboratory attended the session. One of the key conclusions drawn from the meeting is that no matter what type of physiological monitoring system is used it is imperative that the worker's "deep body" or "core" temperature does not exceed 100.4° F. Research findings presented at the symposium indicated that if a heart rate of 180 beats per minute is reached, it is inevitable that the deep body temperature will rise to 103.6° F. A heavy metabolic workload can produce a high heart rate along with the resulting high deep body temperature even though the work environment is not hot. When the high workload occurs in a hot fire situation, physiological stress is likely. Many people at the symposium felt that heart rate monitoring would be a far better method than actually taking temperature to insure that a worker's deep body temperature does not exceed 100.4° F. This temperature should not be exceeded if, as previously stated, the worker's heart rate is not over 110 beats per minute after the first minute's rest and continues to drop at least 10 beats in the next 3 minutes.

From the data collected on fires we find that when temperatures were high the heart rates were only slightly higher than those recorded on cool days. From this we can assume that the crews are pacing themselves according to the temperature.

Based upon industry data presented at the symposium, it appears from a physiological standpoint that fighting forest fires is a relatively tough job in comparison with many industrial jobs. The pulse rates recorded on fire crews are higher and remain higher for a longer period than those reported in industry. Dr. Sharkey says that the metabolic workload fighting fires averages around 420 kilo calories per hour compared with industrial workloads in many cases of from 180 to 240 kilo calories per hour.

Unfortunately, due to the methods used by the Forest Service in reporting illnesses it is not possible to analyze past heat-caused disorders. Disorders that can occur when the deep body temperature exceeds 100.4° F. are heat stroke, heat exhaustion, heat cramps, heat syncope and heat rash.

In Dr. Sharkey's comments following the symposium he notes that in spite of the fact that several speakers at the NIOSH conference made reference to fitness (one individual proposed a fitness test similar to that used by the Forest Service) and in spite of the overwhelming evidence available in the research literature, the initial standards make no reference to physical fitness as a factor contributing to the ability to acclimatize and work in the heat. (Note: Physical fitness has been given token recognition in revisions.) In discussing fitness he notes that the major physiological effect of heat exposure is a diversion of a considerable proportion of the blood volume away from the working muscles to the skin, for purposes of heat dissipation. This is accomplished by radiation, conduction and evaportion.

Physically fit individuals have a larger cardiac output which is measured by heart rate x stroke volume. Their stroke volume is higher and therefore the heart rate is lower than a less fit individual doing the same job. Fit workers also have larger blood volumes and are more efficient at blood redistribution, thus they are better able to work in hot environments. Firefighters rating in the top three categories of the Forest Service Fitness Test have the cardiovascular capabilities needed to accomplish most fire tasks if provided adequate rest breaks and cool, salted water.

DISCUSSION

The designation of one crewmember as a data collector did not cause any particular morale problems among crewmembers or fire overhead personnel. His wages were paid from MEDC project funds during the time spent collecting data. Although this man did not carry tools, by the time he completed all of the measurements, including chains of fireline produced, his job was frequently more difficult than the lineworker's. The measuring equipment gave few problems and other than designing a lightweight holder for the WGT instrument the equipment would be recommended for use should the study be resumed in the future. The WGT instrument needed cleaning periodically as it collected dust, dirt and retardant on the black cloth covering. A new enclosed instrument that would eliminate the dirt problem may be available in the future.

When all of the data were coded for analysis it was felt that there would certainly be several of the variables such as WGT, resistance to control or possibly crew fitness that would strongly influence fireline production. This did not occur and, although it is possible an inadequate amount of data was used, there is also a strong possibility that unmeasured variables have a greater influence. These could include worker skills, training and background and some that are more difficult to measure, such as morale, motivation and supervision. Measurement of these variables and their influence on fireline production would make an interesting future project.

The Forest Service Physical Fitness Test was given to all crews mainly to provide a fitness level to be used along with the other variables in the analysis. This test was given first after the initial training period and then again toward the end of the season. Of the six crews tested each year only 6 percent of the crewmembers rated below the top three categories on the first test and dropped to less than 1 percent on the later test. One of the two crewmembers who did not show improvement during the season was also much older than the average age of the rest of the crew. One of the qualifications for members of Interregional fire crews should be that the individual rate in the top three categories of the fitness test and be able to maintain this level throughout the season. Crew leaders should also use caution in picking up unfit people to bring late season crews up to strength.

The initial proposed NIOSH standard for work in hot environments recommends providing 0.1 percent salted water or salt tablets. Salt depletion can result in loss of appetite and nausea and with further depletion to vomiting and diarrhea. This causes the body to lose additional salt and if not corrected could result in death. The 0.1 percent salted drinking water and salting foods at mealtime are the most desirable methods of avoiding salt depletion. Recent studies show salt tablets should not be used as certain individuals may have a low tolerance to solid salt and the concentrated salt may cause gastric disorders. The greatest risk of salt depletion is with unfit and unacclimatized individuals. The proposed standard does not mention the need for potassium replacement. Recent evidence suggests that potassium loss may have long term disastrous effects and should be considered along with salt replacement. Raisins, prunes and prune juice are a good source of potassium, along with the fresh fruit and citrus fruit juices that are often served in fire camps. The citrus fruits and juices are also a source of Vitamin C which aids in reducing stress and firefighting related illnesses.6/

With the increasing use of women firefighters, fire overhead personnel should be aware of the difference in heat tolerance between men and women. Studies have shown that women reach a higher deep body temperature before sweating begins and that they found heat stress intolerable sooner than

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6/ Cloward, Philip V. and Bill E. Williams. Vitamin C is an "ounce of prevention". Fire Control Notes, Vol. 33, No. 3.

men in work-stress studies. Pulse rates ran 20 to 30 beats per minute higher for women in studies at workloads comparable to firefighting. The higher pulse rates in the women reflect both the heat stress and the physical work but are probably higher mainly because the work is relatively harder for them. The oxygen consumption in milliliters-per-kilogram of body weight was about 15 to 20 percent higher in the women. In spite of the greater strain, women do have the capability to acclimatize and apparently reach the same degree of acclimatization as men.

Fire managers should also be aware of the possible dangers in assigning persons over 45 years old to hot fireline duty. The incidence of heart disorders begins to increase beyond this age and the added cardiovascular strain from hard work in a hot environment by an unacclimatized person could cause serious problems.

There are several actions that fire managers can take to minimize heat stress. If falling or rolling material does not create too great a hazard, much more can be accomplished by working at night when temperatures are cooler and the fire is quieter. Provisions must be made, however, to assure that night crews can get adequate sleep during the day. If conditions are too hazardous for night work an effort should be made to get crews on the line as early in the morning as possible to take advantage of the coolest part of the day. Crews will be able to build more fireline when it is cool and will be in better condition to hold it or begin mopup during the hot afternoon. Mopup data gathered during the study indicate that pulse rates were only slightly above the individual's resting pulse rate even on relatively warm days.

When crews must work on a hot fire during the heat of the day, heat stress buildup can be reduced by avoiding direct attack. With the indirect attack method the burnout fires are less intense and only a small portion of the crew is exposed to the radiant heat.

CONCLUSIONS

1. Firefighters working on wildfires are at times exposed to a hot, stressful environment that can be hazardous to their health.

2. Worker rest breaks are not always adequate, especially when the WGT index is 72 and above.

3. Fireline production rates in current guides are too high in most cases.

4. Physical demands and production rates for various tools and firefighting tasks cannot be established with this amount of field data.

5. Certain factors significantly affecting fireline production cannot be explained by the field data and are apparently dependent upon unmeasured items such as crew skill, training, motivation and supervision, or inadequate study design or data collection procedures.

6. The water intake of firefighters checked during the study was far below the amount needed to offset sweat loss.

7. The high fitness level and the ability of crews to pace themselves when working in a hot environment apparently has contributed to a relatively low occurrence of heat disorders.

RECOMMENDATIONS

1. The Forest Service should continue to monitor the development of the NIOSH Standard for Occupational Exposure to Hot Environments.

2. Fire Safety Officers and Division and Sector Bosses should be trained to recognize or measure hot, stressful environments where heat disorders are likely to occur and to spot check heart rates to assure that workers are receiving adequate rest breaks.

3. The Forest Service Physical Fitness Test should be used to test all personnel subject to duty on the fireline. Only those individuals scoring in the top three fitness categories should be given line duty assignments.

4. The WO Division of Fire Management should consider funding a sequel to this project for the purpose of gathering additional fireline production data so that fireline production rate tables can be revised accurately, and to learn more about the hot environment work situation and how to best cope with it.

5. Equipment and procedures should be developed to deliver adequate quantities of drinking water to firefighters.

6. The findings of the study should be communicated to fieldmen via an article in *Fire Management*, and through training sessions.

SHEET ____

FIREFIGHTERS PHYSIOLOGICAL STUDY

REGION	FIRE NAME	ELEVATION
FOREST	RECORDER	DATE

	TIME															
TEMP	WGT															
	WET BULB															
	DRY BULB															
TOPO	SLOPE															
	FIRELINE GRADE															
	ASPECT															
FUEL	TYPE															
	SPREAD RATE															
	CONTROL RESIST.															
FIRE FRONT	FLAME HEIGHT															
	FRONT DEPTH															
	FRONT WIDTH															
PRODUCTION	CLEAR WIDTH															
	LINE LENGTH															
	LINE WIDTH															
	WORK TASK															
	SMOKE															
NAME	PULSE															
	REC PULSE															
	EFFORT															
NAME	PULSE															
	REC PULSE															
	EFFORT															
NAME	PULSE															
	REC PULSE															
	EFFORT															
NAME	PULSE															
	REC PULSE															
	EFFORT															
	TOTAL MANPOWER															

	HOURS SLEEP	MEALS		WATER INTAKE
		TIME	MENU	
1. ____________ (NAME)				
2. ____________ (NAME)				
3. ____________ (NAME)				
4. ____________ (NAME)				

COMMENTS—

FIREFIGHTERS PHYSIOLOGICAL STUDY
RECORDING AND DATA COLLECTION PROCEDURES

1. <u>Sheet Number</u> - Record number of sheet and number of total data sheets for a given fire. For example: If four sheets are used to record data for a given fire, sheet numbers will be 1/4, 2/4, 3/4 and 4/4.

2. <u>Region</u> - Record the Region data is collected in, NOT the Region you are from.

3. <u>Fire Name</u> - Official fire name.

4. <u>Elevation</u> -

   Record - Average elevation crew is working at for a given day, to nearest 100 feet.

   How to obtain - From contour map or by asking fire overhead.

5. <u>Forest</u> - Name of Forest in which fire is located.

6. <u>Recorder</u> - Your name.

7. <u>Date</u> - Month, day and year.

8. <u>Time</u> -

   Record - Time on 24-hour clock system (example: 8:30 p.m. record as 2030).

   Each day should begin with a new sheet. If you go to a fire at 2:00 p.m. (1400 hours) your sheet might look something like the example.

   Beginning at 0000 hours, record the day's events for the crew. Use averages. If most of the crew was on a party and didn't get to bed until 2:00 a.m. (0200 hours), show 0000-0200 on the form as night life or partying. If one of the subjects for the day did not get to bed until 0400 hours, make a note in the comments section.

If you run out of space on the sheet, continue recording data for the day on a second sheet, sheet No. 2/4. Start new sheet 3/4 for following day, 8/16/71.

9. WGT - This is an abbreviation for Wet Globe Thermometer.

Record - WGT temperature to nearest degree.

How to measure - WGT measurements should be taken every 30 minutes in the vicinity where the test subjects are working. Prior to taking worker's pulse rate, hang the WGT instrument on its support rod for five minutes to allow the ball temperature to stabilize.

WGT Instrument - Refer to manufacturer's use instructions.

a. Keep black sock as clean as possible. Store in sealed plastic bag when not in use. Keep bulb moist at all times.

b. Fill only with distilled water.

c. If sock gets dusty or dirty, rinse in cool, clean distilled water.

10. Wet and Dry Bulb Temperatures

Record - Temperatures to nearest degree.

How to measure - These measurements are taken with sling psychrometer at hourly intervals. Be sure to:

a. Take in the shade or shade the psychrometer with your body.

b. Stand clear of obstacles.

c. Soak wick in distilled water.

d. Twirl psychrometer. Stop and read at 30 second intervals.

e. Read and record readings on the two thermometers when wet bulb reaches its lowest reading.

f. Keep wick on wet bulb clean and do not touch with fingers.

11. Slope

Record - Percent slope crew is working on, to the nearest full percent. Select a typical or representative slope. Measure at 30 minute intervals.

How to measure - Measure slope with clinometer, sight at object at your eye level.

12. Fireline Grade

Record - Percent grade (to nearest full percent)of constructed fireline. If grade varies significantly, select representative measurement. Record + or - % depending upon the direction the crew is working.

How to measure - Clinometer, see slope measurement.

13. Aspect - Aspect is a term used to identify the direction a slope is facing. For example: A slope facing to the south and west has a southwest (SW) aspect.

Record - Aspect should be identified by the use of the following letters: N (North), S (South), E (East), W (West), NE (Northeast), NW (Northwest), SE (Southeast), SW (Southwest).

How to determine - Determine aspect by the location of the sun, off a map or ask the crew boss or other fire overhead if you have any doubts about your interpretation of the aspect. If level, record as an (L) - Level.

14. <u>Fuel Type</u>

Record - Record number for major fuel type heading. For example: Pacific NW fuel type is 82.6. Next record number of fuel condition that you decide best describes the local fuel conditions.

How to determine - Determine from Bureau of Land Mangement Fuel Type Description which is provided. First locate general fuel type area on map. Next, review fuel condition headings and find number and description that best describes the fuel conditions crew is working in.

15. <u>Spread Rate</u> - This is a measure of how fast the fire is spreading.

Record - Using one of the following numbers, record spread rate at the start of line construction. Make a new entry only when spread rate changes in the area the crew is working.

1 - Low rate of spread

2 - Moderate rate of spread

3 - High rate of spread

4 - Extreme rate of spread

How to obtain - Determine from Bureau of Land Management Fuel Type Description L (Low), M(Moderate), H(High), E (Extreme), then convert to numerical designation.

The values listed in the guide are expected rates of spread and should be corrected if the actual on site rates of spread are different. Use your own judgment or ask your crew boss' opinion on the actual rate of spread.

16. <u>Control Resistance</u> - This is a measure of how difficult the fire is to control.

Record - Use same procedure as spread rate.

1 - Low resistance to control

2 - Moderate resistance to control

3 - High resistance to control

4 - Extreme resistance to control

Determine from Bureau of Land Management Fuel Type Description, L(Low),M(Moderate), H(High), E(Extreme), then convert to numerical designation.

The values listed in the guide are expected ratings for resistance to control and should be corrected if the actual on site resistance to control is different. Use your own judgment or ask your crew boss' opinion on the actual resistance to control.

17. <u>Flame Height</u> - Height of flames adjacent the WGT.

Record - Every 30 minutes record flame height to nearest foot. If not applicable, write N/A.

How to obtain - 1. Estimate by comparing height to height of men, trees or other objects.

2. Measure with clinometer - 10% - 100' = 10' ht.

18. <u>Depth of Flame Front</u> - This is the distance or depth of the fire from its outer to its inner perimeter. If not applicable, mark N/A.

How to obtain - Estimate by comparing depth with man's height, or other object.

19. Width of Fire Front - This is the length or distance the front (flames) extends along the outer perimeter.

Record - Record in feet every 30 minutes. If front is long and you cannot see the end, mark block with symbol for infinity (∞). Mark N/A if front does not exist.

How to obtain - Same pacing as for flame height and depth.

20. Clear Width - This is a measurement of the width that trees, brush and other ground and aerial fuels are cleared during construction of the fireline.

Record - During the 30 minute interval between data recordings, measure the cleared width for the fireline in several spots and average them. Record the average cleared width to the nearest foot, i.e., 8. If no clearing, or very little clearing, mark N/A.

21. Line Length - This is a measure of fireline production in length.

Record - During the 30 minute interval between data recordings, measure the length of line produced during the past 30 minute period. Enter measurement in feet. Do not cumulate line production. Only record the production between each data collection interval.

How to obtain - At the 30 minute data collection intervals, mark the place on the fireline where subjects are working when you take their pulse. The next time you stop and take their pulse mark the line

location again. After you take their pulse, measure the distance between the two points on the line.

22. Line Width

Record - Measure and record, in inches, the average width of the mineral soil fireline. If there are marked variations in line width during the period, take several measurements to arrive at an average width.

23. Work Task

Record - The general task the crew is engaged in, the following symbols can be used:

L.C. - Line Construction

M.U. - Mopup

O. - Other (Explain in comments section)

In the empty space following the pulse, recovery pulse and effort columns, list the specific task the subject is performing. For example:

Digging - Pulaski

Clearing - Pulaski

Digging - Shovel

Clearing - Chain saw

See the sample data sheet.

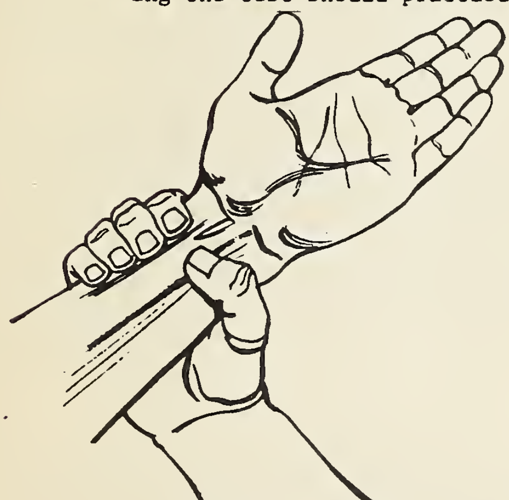
24. Smoke

Record - Use the 1-5 smoke rating system attached to the data collection notebook. Every 30 minutes record the smoke condition in the area the test subjects are working.

25. <u>Pulse</u>

How to obtain - Accurate pulse counts are essential for valid and reliable test results. The count must begin fifteen seconds after the man stops working. The pulse rate is counted for exactly 15 seconds. To count the pulse rate, place the fingertips in the groove directly above the base of the thumb, on the underside of the wrist (see illustration). Count the pulse for 15 seconds and multiply the count by four to get the rate per minute. An <u>alternative location for the pulse count is the side of the throat</u> where very rapid rates are sometimes easier to count.

To gain skill, those responsible for administering the test should practice counting pulse rates.



Approximately every 30 minutes each test subject's pulse should be taken. Pick a time

when you will not interfere with his work task. Experience has shown that less interference and time are involved if pulse is taken on the neck.

Record - Using the table provided convert the 15 second pulse count to rate per minute and record the rate per minute.

26. Recovery Pulse - Recovery pulse should be taken after a rest period just before the subject is ready to go back to work. It is taken and recorded in the same manner as the working pulse rate.

27. Effort - Periodically ask each subject how he perceives his work task in terms of difficulty. Find out if the task is extremely difficult or relatively easy. Use the 1-21 rating scheme mounted on the data collection notebook. Do not show scale to subject.

28. Total Manpower - Record total number of men on specific work task at the time data was recorded.

29. Sleep, Meals and Water

How to obtain - Ask each subject questions on hours of sleep, meals eaten, and water consumed in quarts. You may be able to make notes on these based on your own sleep, eating and drinking history for the day.

30. Comments

Make any comments you wish on any of the data categories or other events that might have a bearing on crew endurance or work production.

RECOMMENDATIONS FOR A STANDARD FOR WORK IN HOT ENVIRONMENTS

The National Institute for Occupational Safety and Health (NIOSH) recommends that employee exposure to heat in the workplace be controlled by requiring compliance with the work practice standard set forth in the following sections. Adherence to the precautionary procedures prescribed will prevent acute or chronic heat disorders and illnesses and heat induced unsafe acts, and will reduce the risk of harmful effects due to the interactions between excessive heat and toxic chemicals and physical agents. The standard is amenable to techniques that are valid, reproducible, and presently available. It will be reviewed and revised as necessary.

A. DEFINITIONS

1. Acclimatization to heat means a series of physiological and psychological adjustments that occur in an individual during his first week of exposure to a hot environment so that thereafter the individual is capable of working in a hot environment without excessive strain.

2. Unimpaired mental performance means the ability of an employee to cope with conditions where safety and health depend on constant alertness because he has to make critical decisions, fine discriminations, or fast and skillful actions.

3. Intermittent heat exposure means exposure to hot environmental conditions which continues no longer than 15 minutes without an interrupting interval spent either spontaneously or according to a prescribed schedule in a cooler environment.

4. Continuous heat exposure means any exposure to hot environmental conditions which is not an intermittent exposure.

5. Hot environmental condition means any combination of air temperature, humidity, radiation and wind speed that exceeds a Wet Bulb Globe Temperature (WBGT) of 79°F. (WGT of 72°F.).

B. APPLICABILITY

The provisions of this standard are applicable to all places of employment, indoors and outdoors, and to all employees except those who are required to wear impermeable protective clothing.

C. WORK PRACTICES

1. For sedentary jobs where continuous unimpaired mental performance is required, no employee shall be exposed to conditions which exceed the limits set forth in figure 1.

2. No employee should be permitted to work without protective observation at high heat stress levels.

3. When exposure of an employee is continuous for 1 hour or intermittent for a period of 2 hours and the time-weighted average WBGT exceeds 79°F. (72°F. WGT) for men or 76°F. (70°F. WGT) for women, then any one or combination of the following practices shall be initiated to insure that the employee's body core temperature does not exceed 100.4°F.

(a) Acclimatization

(1) Unacclimatized employees shall be acclimatized over a period of 6 days. The acclimatization schedule shall begin with 50 percent of the anticipated total workload and time exposure on the first day, followed by daily 10 percent increments building up 100 percent total exposure on the sixth day.

(2) Regular acclimatized employees who return from nine or more consecutive calendar days of leave shall undergo a 4-day acclimatization period. The acclimatization schedule shall begin with 50 percent of the anticipated total exposure on the first day, followed by daily 20 percent increments building up to 100 percent total exposure on the fourth day.

(3) Regular acclimatized employees who return from 4 consecutive days of illness should have medical permission to return to the job, and should undergo a 4-day reacclimatization period as defined in (2) above.

(b) A work and rest regimen shall be implemented to reduce the peaks of physiological strain and to improve recovery during rest periods.

(c) The total workload shall be evenly distributed over the entire workday when possible.

(d) When possible, hot jobs shall be scheduled for the coolest part of the work shift.

(e) Regular breaks, consisting as a minimum of one every hour, shall be prescribed for employees to get water and replacement salt. The employer shall provide a minimum of 8 quarts of cool potable 0.1 percent salted drinking water or a minimum of 8 quarts of cool potable water and salt tablets per man per shift. The water supply shall be located as near as possible to the position where the employee is regularly engaged in work, but never further than 200 feet1/ therefrom.

(f) Appropriate protective clothing and equipment shall be provided and used.

(g) Engineering controls to reduce the environmental heat load shall be utilized.

D. ENVIRONMENTAL MEASUREMENTS

1. The WBGT index used as the parameter in determining the environmental conditions for implementation of work practices shall be calculated by the following equations:

For indoor exposure, or outdoor exposure with no solar load:

$$WBGT = 0.7\ WB + 0.3\ GT$$

1/ Except where a variance had been granted.

For outdoor sunlit exposure:

$$WBGT = 0.7\ WB + 0.2\ GT + 0.1\ DB,$$

where WB = the natural wet-bulb temperature obtained with a wetted sensor exposed to the natural air movement (unaspirated)

GT = globe thermometer temperature

DB = dry-bulb temperature

2. The time-weighted average WBGT shall be determined by the equation:

$$\text{Av. WBGT} = \frac{(WBGT_1) \times (t_1) + (WBGT_2) \times (t_2) + \text{---}\ (WBGT_n) \times (t_n)}{(t_1) + (t_2) + \text{-------------}\ (t_n)}$$

where $WBGT_1$, $WBGT_2$, $WBGT_n$ are calculated values of WBGT for the various work and rest areas occupied during total time period; t_1, t_2, t_n are the elapsed times in minutes spent in the corresponding areas which are determined by a time study.

(a) Where exposure to environmental conditions is continuous for several hours or the entire workday, the WBGT shall be calculated as an hourly <u>time-weighted-average</u>.

(b) Where exposure is intermittent, the WBGT shall be calculated as a 2-hour <u>time-weighted-average</u>.

E. MEDICAL

1. All employees who are 45 years of age and older and who have not had previous occupational exposure to heat shall not be assigned to jobs where the environmental conditions equal or exceed 79°F. WBGT (72°F. WGT) for men and 76°F. WBGT (70°F. WGT) for women, until they are acclimatized.

2. All personnel who are to be assigned to hot jobs for the first time shall be evaluated by a physician prior to assignment to assure that the individual can cope with the hot environment. In the examination special emphasis should be on the cardiovascular, renal, hepatic, endocrine, and respiratory system and the skin. The examination should also include a complete medical history of the worker with specific emphasis on previous heat-related disorders or illnesses.

3. All employees exposed to hot environmental conditions should be given a periodic physical examination every 2 years for employees under age 45, and every year for employees 45 years of age or older, that should include all components of the preplacement examination.

4. There shall be a person available during working hours who shall have had first aid training in recognizing the signs and symptoms of any heat disorder or illness.

F. APPRISAL OF EMPLOYEES OF HAZARDS FROM EXPOSURE TO EXCESSIVE HEAT

Each employee who may be exposed to environmental conditions that exceed the prescribed limits shall be given training in health and safety procedures through a program that shall include the following as a minimum:

1. Information as to water intake for replacement purposes.

2. Information as to salt replacement.

3. Importance of weighing each day before and after the day's work.

4. Instruction on how to recognize the symptoms of heat disorders and illnesses, including dehydration, exhaustion, heat syncope, heat cramps, salt deficiency exhaustion, prickly heat, and heat stroke.

5. Information as to special caution that shall be exercised in situations where employees are exposed to toxic agents and/or other stressful physical agents which may be present in addition to and simultaneously with heat.

6. Information concerning heat acclimatization. The information shall be kept on file and readily accessible to the worker at all places of employment where he may be exposed to excessive heat.

G. WARNING SIGN

The following warning sign shall be appropriately located at one or more places to be noticed by anyone entering an area where environmental conditions are 86°F. WBGT (79°F. WGT) or above.

W A R N I N G

HEAT STRESS AREA

H. MONITORING

1. A WBGT profile shall be established for each work place for winter and summer seasons to serve as a guide for deciding when work practices shall be initiated to conform with the requirements of the standard. The first profile shall be established within 3 months of the effective date of this standard.

2. After the WBGT profiles have been established, monitoring shall be conducted once during July and August of each year.

I. RECORDKEEPING

1. The following records shall be maintained.

   a. Medical records for each employee.

   b. Records of acclimatization as required by section C.3.(1).

   c. Records of the WBGT for each work area as specified in section H.

2. Records required by provisions a. and b. above shall be maintained for a period of the employee's employment and for 1 year thereafter.

3. Records of the WBGT as specified in c. above shall be maintained for a period determined by the Secretary of Labor with consultation with the Secretary of Health, Education, and Welfare.

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